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Investigation on Upgrading the Life of Mechanical Systems During Transport Formed on Quantum-Conveyed Life Protype and Sample Size

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ABSTRACT

To raise the fatigue life of mechanical system randomely vibrated in transit, parametric Accelerated Life Testing (ALT) as organized procedure is proffered, which is generated in life–stress type and sample size. The arranged steps allow engineer to uncover the constructional weakness that has a notable consequence on reliability. Finally, company may halt to occur recalls from the market. As a case, upgrading the life of mechanical systems during transit was examined.

Keywords: Mechanical Product; Mechanical System; Parametric ALT; Transit, Fatigue; Design Imperfections

Introduction

The system worked by machine transmits (generated) power to retain a planned result that necessitates forces & motion and gains mechanical advantages by correctly attaining unknown mechanisms. By carrying out the refrigerating cycle, a household refrigerator allows conditioned air from evaporator to refrigerator & freezer section. In the process, foods in each freezer and refrigerator section can be kept freshly. Refrigerator is formed of compressor, condenser, capillary, and evaporator. It should be devised to properly work under the occurrences actually employed by the end-user. As there are design weakness in the construction, it cannot immediately work in its presumed life (Figure 1). When discovering them by reliability testing, a designer may work out it in the most optimized mode [1]. It holds:

- An ALT scheme,
- Load investigation,
- An ALTs with some alternations, and
- The ability to judge well if product gets to the desired BX lifetime. As an instance investigation, the mechanical systems in transit will be examined.

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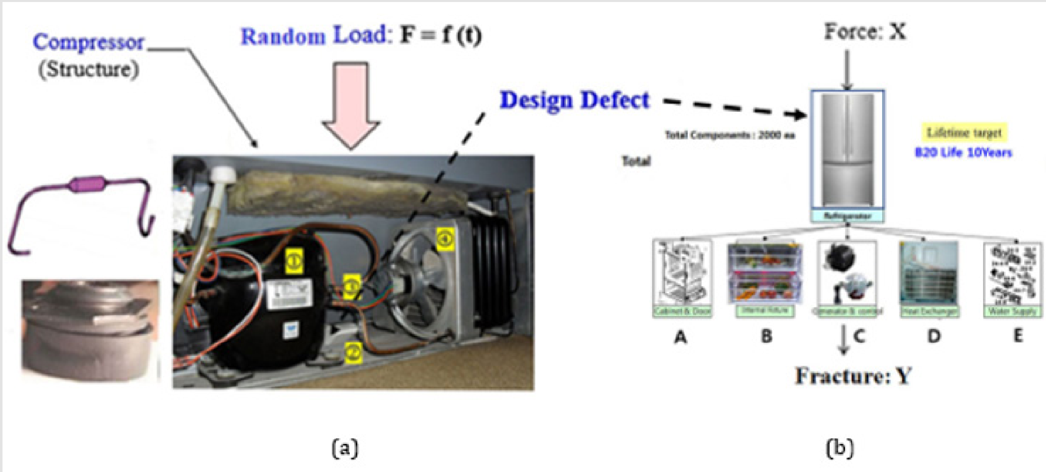

Note:

a) Mechanical department

b) Refrigerator and its modules A-E

Figure 1: Mechanical compartment in refrigerator: compressor [1], rubber [2], connecting tubes [3], and fan and condenser [4].

Parametric ALT in Mechanical Product

Answering for the Schrodinger's governing formulation can be found:

$$-\frac{h^2}{8\pi^2 m}\frac{d^2\psi_n(x)}{dx^2} = E_n\psi_n;\psi_n(x) = \sqrt{\frac{2}{a}}\sin\left(\frac{n\pi}{a}\right)x; E_n = \frac{n^2h^2}{8ma^2}\, n > 0 \quad (1)$$

Linear transport shall be described:

$$J = LX \quad (2)$$

As an instance, solid-state diffusion, J, shall be abridged

$$J = B\sinh(aS)\exp\left(-\frac{E_a}{kT}\right) \quad (3)$$

As Equation (3) places the inverse, the life-stress (LS) type shall be explained:

$$TF = A\left[\sinh(aS)\right]^{-1}\exp\left(\frac{E_a}{kT}\right) \quad (4)$$

In Equation (4) the $[\sinh(aS)]^{-1}$ has some properties:

1) $(S)^{-1}$ in the inception has just about line effect,

2) $(S)^{-n}$ is discovered as a midway effect, and

3) $(e^{as})^{-1}$ in the complete is immeasurable. In the midway effect, an ALT is accomplished.

As the effect materializes from effort in transmitting power, Equation (4) shall be restated as:

$$TF = A(S)^{-n}\exp\left(\frac{E_a}{kT}\right) = B(e)^{-\lambda}\exp\left(\frac{E_a}{kT}\right) \quad (5)$$

To attain the acceleration factor (AF), declared as the relatedness between the raised-level stress and ordinary stress, it shall be defined as:

$$AF = \left(\frac{s_1}{s_0}\right)^n\left[\frac{E_a}{k}\left(\frac{1}{T_0}-\frac{1}{T_1}\right)\right] = \left(\frac{e_1}{e_0}\right)^\lambda\left[\frac{E_a}{k}\left(\frac{1}{T_0}-\frac{1}{T_1}\right)\right] \quad (6)$$

To achieve the mission cycles for aimed life - B1 life of ten years, sample size unified with Equation (6) may be defined as [2]:

$$n \geq (r+1).\frac{1}{x}.\left(\frac{L_{BX}^*}{AF.h_a}\right)^\beta + r \quad (7)$$

Case Investigation: Upgrading the Fatigue Life of a Household Refrigerator Exposed to Random Vibrations in Transported by Rail

Refrigerators were transported from the Los Angeles located in the West Coast to consumers who resided in the East Coast of the United States. This journey of seven days was 7,200 km for a whole travel period. As stated by field statistics, after refrigerators exposed to random vibrations in the rail transportation route (US) were shipped, they did not function because the compressor rubbers were torn and the attaching tubes were broken, accompanying by designers to ask for replacing it. That is, in the US, the interval at which first unsuccessfulness happened over two days was about 2,500 km in rail transit. In Chicago, 27% of the conveyed products was unsuccessful.

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As the refrigerators moved the 7,200-km interval from West Coast to Boston over seven days, 67% of the products was unsuccessful. It was obvious that the failed refrigerators had design defects. To correctly function the refrigerator for its presumed life in transit, after identifying them by laboratory tests such as parametric ALT, the manufacturer had to modify the problems (Figure 2).

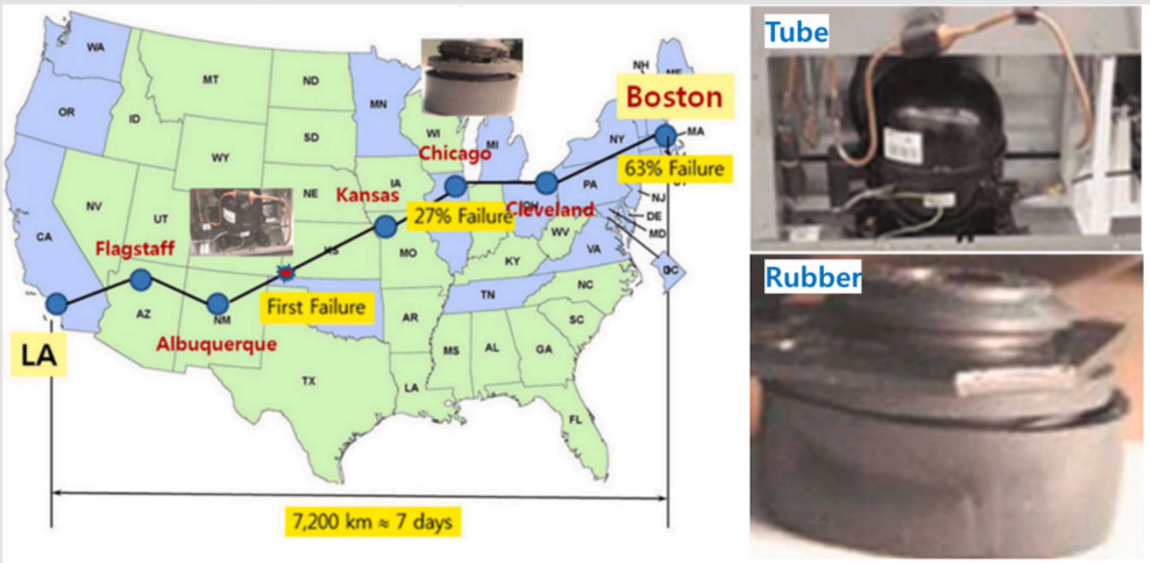

Figure 2: Failed places and product from the marketplace.

Due to the foundation load, Y, the force transmissibility, Q, can be expressed:

$$Q = X(t)/F_T(t) = X(t)/Y(t) = \left[\frac{(2\varsigma \frac{fn}{f})^2 + 1}{(1-(\frac{fn}{f})^2)^2 + (2\varsigma \frac{fn}{f})^2} \right]^{1/2} \quad (8)$$

where X is the unvarying solution in a physical process, F_T is the induced force, Y is the span of base excitations, r is the frequency proportion $= \omega_n/\omega = f_n/f), \varsigma$ is the damping proportion $= C/C_C = C/2\omega_n)$, k is the spring quantity.

As the stress in transportation comes from the conveyed vibration loads, F_T, which may be stated as the power spectral density (PSD) level of acceleration for a determined frequency band, Equation (5) may be expressed:

$$TF = A(S)^{-n} = B(F_T)^{-\lambda} \quad (9)$$

Thus, found on Equation (6), the AF can be stated:

$$AF = \left(\frac{s_1}{s_0}\right)^n = \left(\frac{a_1}{a_0}\frac{X}{Y}\right)^{\lambda} = (R \times Q)^{\lambda} \quad (10)$$

where a1 is the raised PSD level for the given frequency band, a_0 is the usual PSD level for the given frequency band, R, amplitude ratio of gravitational acceleration. After examining the calculated vibration spectra, the natural frequencies of vibration (left ↔ right and up ↔ down) were 5 Hz and 9 Hz. The damping ratio was expected to have ζ = 0.1 with a settling time of 2 sec and about 5% overshoot. The frequency proportion also was expected to have r $(\omega/\omega_n)=1$ at the natural frequency ω_n. To achieve the AF in the horizontal/vertical orientations of random vibrations discovered from the market, raised PSD loads to the refrigerator were exerted on the shaker bench for each direction (Figure 3). The force transmissibility, Q, had the extent of about 5.3 from Equation (8). Because of acceleration of 1 G_{rms}, the AF was 4.0, estimated to that of worst-occasion of 0.25 G_{rms}. Utilizing a cumulative damage constant, λ, of 2.0, the whole AF in Equation (10) was established to have 450.0. Because the computed shape parameter in the Weibull chart was 6.41 and the lifetime target – B1 life for the entire travel interval had, the test period obtained from Equation (7) was about 40 minutes for three samples. That is, if the refrigerator was unsuccessful less than once in mission time – 40 minutes, refrigerator was acceptable for the entire travel interval of 7,200 km to survive the fatigue damaged due to random vibration.

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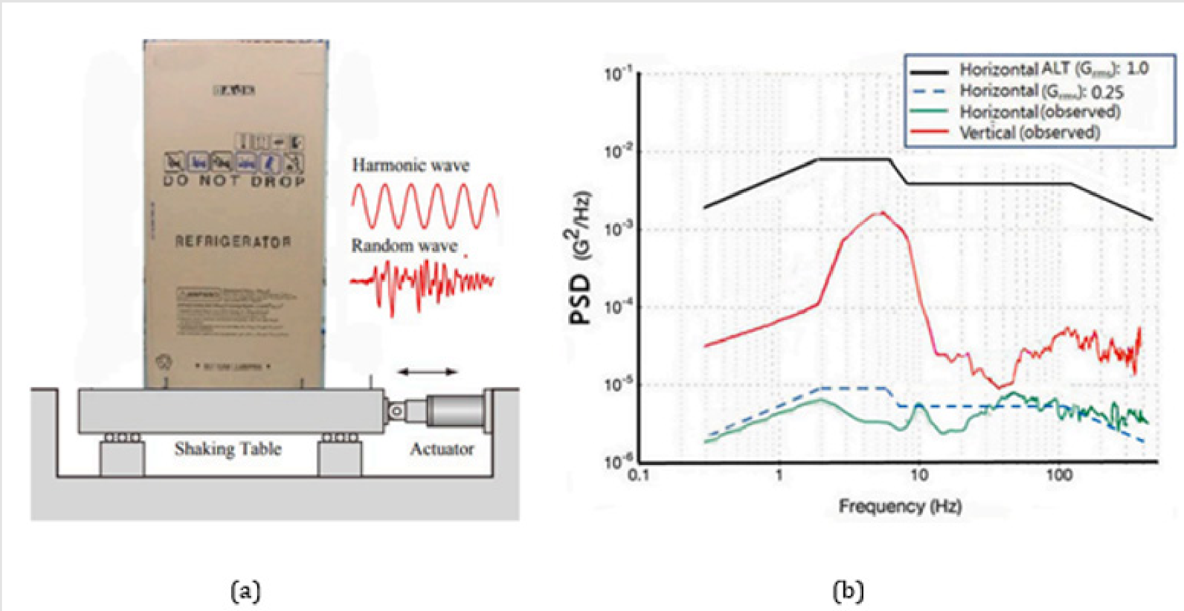


Note:

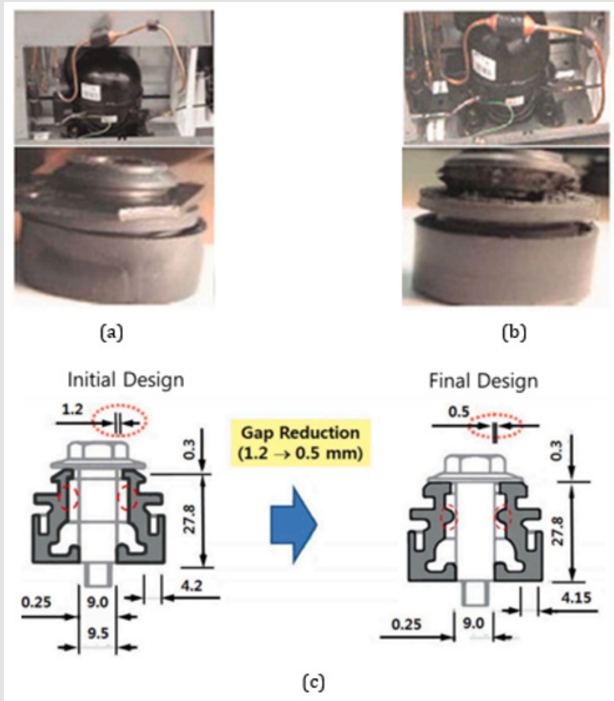
a) Shaking table

b) Applied PSD loads

Figure 3: Programmed PSD loads on shaking table.

Results and Conclusion

In the 1st ALT, the failures of the stress levels — 1.00 G_{rms} at the natural frequency $(r = 1.0, \zeta \approx 0.1)$ were achieved. That is, for these conditions, rubber mounts were torn and tubes were broken at 20 min in the refrigerator samples. It occurred because there was no support in the region of stress raiser for the rubber mount to withstand the repeated random loads due to horizontal vibrations (left ↔ right). As alterations, the refrigerator was redevised as the modified compressor rubber mount, C1(Figure 4). In 2nd ALT, the refrigerator did not fail until 60 minutes. As refrigerator arrived at an acceleration of 1.00 Grms on the bench, the natural frequency – 5 Hz – in the horizonal orientation was changed to 8 Hz by the increased damping (Figure 5). To expand the fatigue life of system such as refrigerator in transportation, parametric ALT was evolved. The quantum-transported life-stress formulation and sample size were proposed. As an instance examination, improving the fatigue life of a refrigerator failed by random vibrations in rail transit was studied. After the compressor mounts was redesigned, there were no problems for mission period – 40 min. Therefore, the household refrigerator was reassured to outlive the fatigue created and accomplish the product life – B1 life for the complete travel interval.



Note:

a) Field

b) 1st ALT outcomes

c) Design modifications

Figure 4: Fatigued refrigerator from the field and 1st ALT.

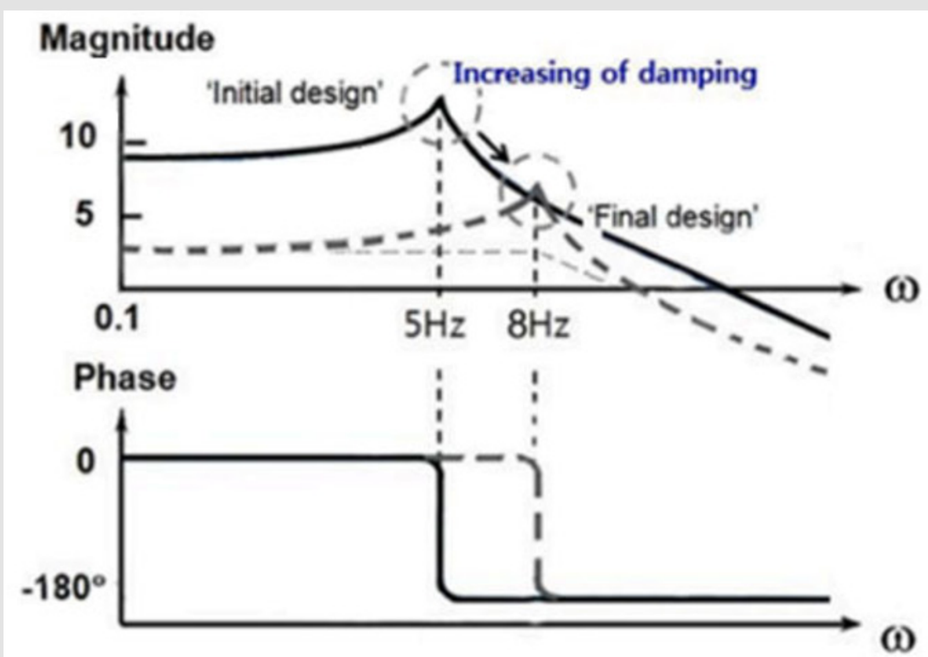


Figure 5: Changed natural frequency in the horizontal vibration.

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